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Spatial distribution of soft-bottom molluscs in the Ensenada de San Simón (NW Spain)

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Abstract: Distribution and abundance of the molluscan fauna was studied in the intertidal and subtidal soft-bottoms of the Ensenada de San Simón (NW Spain). Depth, grain size, and total organic matter were the most important factors in determining distribution patterns of molluscs in this inlet. Three major malacological assemblages have been determined in the Ensenada de San Simón, two of them subdivided in two facies. In the intertidal area of the inlet, one facies (A1) was located in areas associated with seagrass meadows of *Zostera* spp. and was dominated by *Hydrobia ulvae* (Pennant, 1777) whereas the second facies (A2) had a high dominance of *H. ulvae*, *Cerastoderma edule* (Linnaeus, 1758), and *Tapes decussatus* (Linnaeus, 1758). An impoverished facies of this community was present in reduced, muddy bottoms (Group C). In the subtidal bottoms, one group (B1) was located in the central part of the inlet with *H. ulvae, Rissoa labiosa* (Montagu, 1803), *Turboella radiata* (Philippi, 1836), *Parvicardium exiguum* (Gmelin in Linnaeus, 1791), *Loripes lacteus* (Linnaeus, 1758), and *Abra nitida* (Müller, 1789) as characteristic species. A second facies (B2) was found in outer areas of the inlet, characterized by *Thyasira flexuosa* (Montagu, 1803), *Mysella bidentata* (Montagu, 1803), *Abra alba* (Wood, 1802), and *Nucula nitidosa* Winckworth, 1930.

Key words: macrofauna, *Macoma* community, *Abra alba* community, multivariate analysis, Atlantic Ocean

Several faunistic and ecological works on the macrobenthic communities of the Iberian and Galician coasts of Spain have been carried out in recent years (Anadón 1980, López-Jamar and Mejuto 1988, López-Jamar and Cal 1990, Troncoso and Urgorri 1991, Mazé *et al.* 1993, Junoy 1996). Benthic communities are considered good indicators of marine bottom conditions (Pearson and Rosenberg 1978, Grall and Glémarec 1997). The Ensenada de San Simón is located in the inner part of the Ría de Vigo, the southern-most of the Galician estuaries. These estuarine systems have been studied because of their great economic and social importance, including fisheries, raft mussel cultures, and shellfish resources.

Benthic communities of the Ría de Vigo have been analyzed since 1886 when Hidalgo published a list of marine species of the NW Spanish coast (Hidalgo 1917). Despite the abundance of studies in the Ensenada de San Simón (Nombela *et al.* 1995, Fernández Rodríguez *et al.* 1997, Álvarez-Iglesias *et al.* 2003), few researchers have analyzed patterns of benthic faunal spatial distribution, and none have quantified community structure. While the molluscan fauna was studied in other estuaries (Troncoso *et al.* 1996, 2005, Olabarría *et al.* 1998), the only previous studies in the Ría de Vigo were by Rolán (1983), Rolán *et al.* (1989), and Moreira *et al.* (2005).

Consequently, there is a need to improve our knowledge to ensure correct management and conservation in the area, especially due to Ensenada de San Simón being included in the Nature 2000 Network as a Special Conservation Zone. Therefore, the aim of the present study is to describe and quantify the malacofaunal communities and associations inhabiting intertidal and subtidal soft substrata throughout the Ensenada de San Simón. Characteristic and dominant species are studied to document their relationship with several environmental variables.

MATERIALS AND METHODS

Study area

The Ensenada de San Simón is located in the inner part of the Ría de Vigo (NW Spain), between 42°17′ and 42°21′N and between 8°37′ and 8°39′W (Fig. 1). The seagrasses *Zostera noltii* and *Zostera marina* cover the intertidal and shallow subtidal areas. Considerable freshwater input occurs in the inner-most part of the inlet which results in salinity fluctuations on a tidal and seasonal basis (Nombela and Vilas 1991). Culture of mussels on rafts is a common practice in large areas of the mouth of the inlet, and a small harbor is located in the mouth of the Alvedosa River.

Sampling and sediment laboratory analysis

Samples were collected during November and December 1999 from 29 sites (Fig. 1). Five samples were taken at each site, by means of a van Veen grab (0.056 m^2). Samples were sieved through 0.5 mm mesh and the retained material was fixed in 10% buffered formalin. Fauna was sorted from the sediment and preserved in 70% ethanol. Temperature

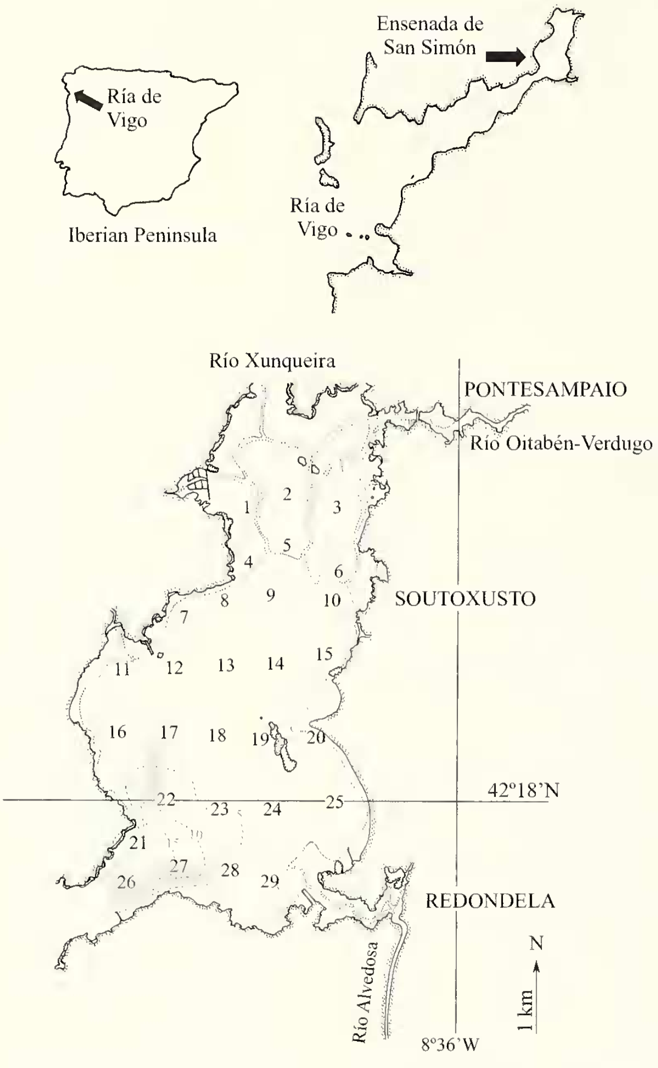

Figure 1. Study area showing the location of sampling sites in NW Spain. Gray figures represent mussel raft sites.

and pH were measured *in situ* from water and sediment samples taken from each site. An additional sediment sample was taken at each site for grain-size, calcium carbonate, and total organic matter content analyses. Granulometric fractions and sediment types were determined. The median grain size (Q_{50}, mm) and the sorting coefficient (S_o) were also calculated for each sample (Trask 1932). Calcium carbonate content (%) was estimated by sample treatment with hydrochloric acid, and total organic matter content (%) was estimated from the weight loss after combustion by placing samples in a furnace for 4 hours at 450 °C (Guitián and Carballas 1976, Parada *et al.* 1993).

Data analysis

Abundance (A), species richness (S), Shannon-Wiener's diversity index (H', $\log_2$) (Shannon and Weaver 1963), and Pielou's evenness index (J) (Pielou 1984) were determined for the five samples pooled in each site (0.28 m^2). Dominance was calculated as the percentage of the numbers of individuals belonging to one species with respect to the total number of specimens in that sample. Mollusc assemblages were based on the analysis of the species abundance data matrix by non-parametric multivariate techniques, using PRIMER software (Clarke and Warwick 1994). A similarity matrix was calculated, using the Bray-Curtis coefficient, after applying the fourth-root transformation to species abundance. From the similarity matrix, classification and ordination of the sites were analyzed: cluster analysis, algorithm UPGMA, and non-metrical multidimensional scaling, MDS. The SIMPER program was used to identify molluscan species that contributed to dissimilarity among groups.

Species were classified according to the constancy and fidelity indexes and to the fidelity-dominance product (Dajoz 1971). Relationships between abundance of molluscs and environmental variables were studied by means of the BIOENV procedure (PRIMER package) and canonical correspondence analysis (CANOCO package; ter Braak 1988). Environmental variables in percentages were transformed by logarithm (x+1) and all were normalized.

RESULTS

Sedimentary characterization

The soft bottoms of the Ensenada de San Simón were characterized by a predominance of muddy sediments with a high total organic matter and low calcium carbonate content (Appendix 1). Sandy sediments were present in tidal channels in the inner inlet where low total organic matter content was also found. Areas around the outer part of the inlet had muddy sands with a large gravel fraction composed of the mussel shells cultured there.

Molluscan fauna

A total of 24,605 individuals belonging to 68 species of molluscs (30 bivalves, 34 gastropods, 3 polyplacophorans, and 1 scaphopod) was sampled in the study area (Appendix 2). Gastropods were the most abundant group (88.92% of the total mollusc abundance) due mainly to large numbers of *Hydrobia ulvae* (Pennant, 1777). This hydrobiid showed densities of up to 34,946 individuals/m^2 in sandy bottoms of tidal channels and 14,800 individuals/m^2 in sediments colonized by *Zostera marina* and *Z. noltii* in the innermost part of the inlet. Other dominant gastropods were *Rissoa labiosa* (Montagu, 1803), *Turboella radiata* (Philippi, 1836), and *Chrysallida terebellum* (Philippi, 1844), mainly in intertidal and shallow bottoms. Bivalves were numerically the second most important group (10.99% of total) with the greatest numbers in the central area and at the mouth of the inlet.

The most abundant bivalves were *Cerastoderma edule* (Linnaeus, 1758) in sandy intertidal sediments and *Thyasira flexuosa* (Montagu, 1803), *Mysella bidentata* (Montagu, 1803), and *Abra alba* (Wood, 1802) in subtidal sediments. Polyplacophorans and scaphopods were found in small numbers (0.09%).

The highest abundances of molluscs were recorded at sites 6, 2, and 3 due to the high abundance of *Hydrobia ulvae*; the lowest were recorded at sites 24 and 28 (64.3-342.9 individuals/m^2). Sites 26, 27, and 22 at the mouth of the inlet showed the highest species richness (22-31). Only two species were found at sites 29 and 24, located in the mouth of the Alvedosa River. Shannon-Wiener's diversity index varied between H′ = 0.09 (site 3) and 3.75 (site 27), and evenness ranged from J = 0.04 (site 3) to 0.97 (site 24). Greatest H′ values were recorded in sites in the mouth of the inlet while the lowest values were found in intertidal sites with high numbers of *H. ulvae.*

Spearman's correlation coefficient indicated that depth was positively correlated with species richness ($r_s = 0.511$, $N = 29$, $P < 0.01$), diversity ($r_s = 0.639$, $N = 29$, $P < 0.01$), and evenness ($r_s = 0.568$, $N = 29$, $P < 0.01$), and negatively correlated with number of individuals ($r_s = -0.458$, $N = 29$, $P < 0.05$). Species richness was positively correlated with percent content in gravel ($r_s = 0.470$, $N = 29$, $P < 0.05$) and was negatively correlated with total organic matter ($r_s = -0.401$, $N = 29$, $P < 0.05$) and silt/clay content ($r_s = -0.376$, $N = 29$, $P < 0.05$). The number of individuals was positively correlated with percent calcium carbonate, median grain size ($r_s = 0.596$ and $r_s = 0.473$ respectively, $N = 29$, $P < 0.01$) and sand content ($r_s = 0.500$, $N = 29$, $P < 0.01$) and negatively correlated with silt/clay content ($r_s = -0.511$, $N = 29$, $P < 0.01$).

Multivariate analysis

The classification diagram based on abundance data showed three main groups: A, B, and C (Fig. 2). These three groups were further subdivided into five subgroups. Group A1 had muddy sediment, sandy mud, and very coarse sand. Group A2 was composed of coarse sand and muddy sand bottoms. Group B1 was comprised of muddy sediments (mud and sandy mud to muddy sand). Group B2 sites had mud and muddy sand bottoms. Group C sites had muddy sediments. This classification agreed with ordination of sites obtained through non-metrical multidimensional analysis (Fig. 3).

Water depth presented the highest correlation with faunistic data according to the BIOENV procedure (Spearman's rank correlation $\rho_w = 0.312$). It was followed by the combination of depth and median grain size ($\rho_w = 0.201$), and that of bottom water temperature, very fine sand, fine silt, clay, and depth ($\rho_w = 0.192$).

In the canonical correspondence analysis, the first two axes accounted for 44.4% of the total variance of species-environment relationships and 34.0% of the species variance (Table 1). Species-environment correlations close to 1 indicated that abiotic variables were correctly chosen (ter Braak 1988) while the maximum eigenvalue reached in the first axis was close to the optimal 0.7. Bottom water and sediment temperature, coarse and fine silts, clay, and calcium carbonate showed the highest correlations with axis I; however, correlations with other axes were less significant. Forward selection indicated water depth as the variable explaining most of the variance in the species data ($F = 3.82$, $P < 0.01$) as well as bottom-water temperature ($F = 1.82$, $P < 0.05$), total organic matter ($F = 1.73$, $P < 0.05$), clay ($F = 1.63$, $P < 0.05$), and very fine sand ($F = 1.91$, $P < 0.05$). The scatter diagram showed an ordination of sites following a gradient of depth and grain size (Fig. 4). Sites from Group A1 and A2 were progressively distributed along the negative part of axis I, in intertidal or shallow waters with coarse sediments; sites from group B1 and B2 were deeper with greater content in finer sedimentary fractions.

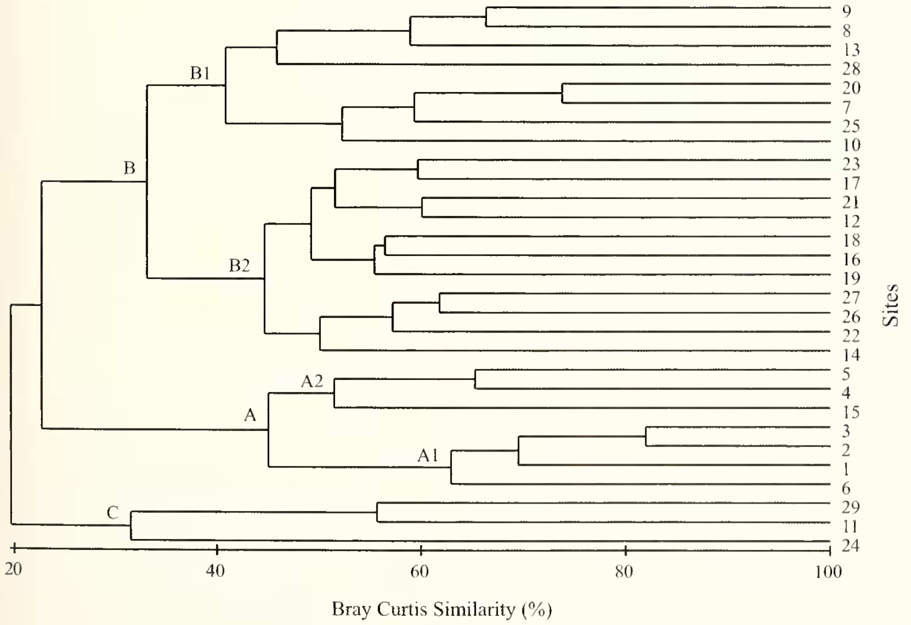

Figure 2. Dendrogram showing the groups and subgroups considered.

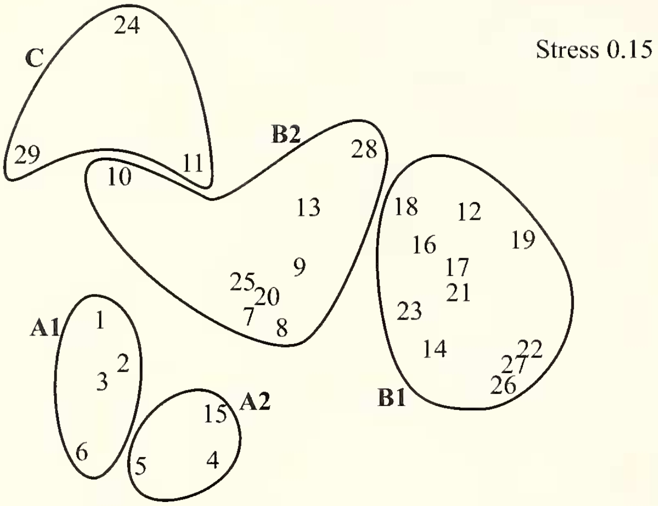

Figure 3. Ordination diagram representing the assemblages considered in the classification analysis. Numbers refer to sites. Stress indicates the goodness-of-fit for the model: the smaller the stress, the better the representation.

The analyses suggested that the distribution of molluscan fauna is mainly determined by depth, organic matter content, and grain size gradients.

Description of assemblages

Classification and ordination analyses differentiated five different assemblages (Tables 2-3, Fig. 5). Group A located in the inner-most part of the inlet, in intertidal sediments close to the mouth of the Oitabén-Verdugo and Xunqueira Rivers. The most abundant species was *Hydrobia ulvae*, mainly in bottoms colonized by *Zostera noltii*. Subgroup A1 was comprised of four intertidal sites located along the northern border of the inlet in heterogeneous sediments. These bottoms exhibited low species richness (S = 11). The seagrasses *Zostera marina* and *Z. noltii* were spread across most of these bottoms. The most characteristic species according to values of fidelity-dominance product (F × D) were *H. ulvae*, *Chrysallida terebellum*, and *Cerastoderma edule*. This area had the smallest mean diversity value due to the high dominance of *H. ulvae*. SIMPER analysis showed that *H. ulvae* and *C. edule* were the species with a greater similarity contribution (75%) for this group. Subgroup A2 was located in the intertidal sandy bottoms with the greatest content in coarse sand (23.2% ± 17.5, mean ± *SD*) and the greatest median. A total of 28 species was found, and the most characteristic, according to F × D, were *H. ulvae*, *C. edule*, *Tapes decussatus* (Linnaeus, 1758), *Ostrea edulis* Linnaeus, 1758, *C. terebellum*, and *Retusa truncatula* (Bruguière, 1792). In accordance with the SIMPER analysis, Group A2 was mainly defined by *H. ulvae*, *C. edule*, *R. truncatula*, *T. decussatus*, and *Lepton nitidum* Turton, 1822.

Group B was present in muddy bottoms, from intertidal areas to 28 m depth in the mouth of the inlet. Species richness increased from sites in inner areas towards the mouth. Sediments were mainly composed of silt and clay (>50%). Subgroup B1 was defined in shallow sediments in the center of the inlet (0-4.7 m depth). Sites 10 and 20 had *Zostera marina* meadows. This subgroup had 27 species and showed the greatest mean value for evenness. The F × D and dominance values indicated that the most characteristic species were *Hydrobia ulvae*, *Rissoa labiosa*, *Turboella radiata*, *Parvicardium exiguum* (Gmelin in Linnaeus, 1791), *Loripes lacteus* (Linnaeus, 1758), *Abra nitida* (Müller, 1789), and *Chrysallida terebellum*. According to the SIMPER analysis, Group B1 was characterized by *H. ulvae*, *C. terebellum*, *T. radiata*, and the bivalve *P. exiguum*. Subgroup B2 was located in the external part of the inlet, in subtidal bottoms (3.7-28.2 m). These bottoms showed the highest mean value for calcium carbonate. Fifty-nine molluscan species were found and many of them showed great Fidelity values. Among the species with highest values of F × D were *Thyasira flexuosa*, *Mysella bidentata*, *Calyptraea chinensis* (Linnaeus, 1758), *Abra alba*, *Nucula nitidosa* Winckworth, 1930, and *Hyala vitrea* (Montagu, 1803). Other species with high values of constancy and fidelity were *Myrtea spinifera* (Montagu, 1803), *Chrysallida fenestrata* (Jeffreys, 1848), and *Corbula gibba* (Olivi, 1792). The bivalves *T. flexuosa*, *M. bidentata*, *A. alba*, *N. nitidosa*, and gastropod *C. chinensis* defined group B2, according to SIMPER.

Group C was mainly characterized by *Hydrobia ulvae* (86% of cumulative similarity). This group was composed of muddy sites close to the mouth of several small rivers and Redondela harbor. Sediments were predominantly composed of silt and clay with low carbonate content, and the greatest values of total organic matter in the inlet. Only 8 species were found and densities were less than in other groups (1202.50 ± 898.21 individuals/m^2). The species with highest values of F × D were *H. ulvae*, *Turboella radiata*, and *Loripes lacteus*, while the group was mainly characterized by *H. ulvae* (86% of cumulative similarity).

DISCUSSION

The distribution of the molluscan fauna seemed to be mainly determined by depth, organic matter content, and grain-size in the Ensenada de San Simón, NW Spain. Intertidal and shallow sediments in inner channels were mostly sandy and then became increasingly muddy towards the deeper bottoms in the center and at mouth of the inlet. The lack of strong currents in the greater part of the inlet and the very common culture of mussels on rafts were responsible

Table 1. Canonical correspondence analysis for the Ensenada de San Simón.

Axes	I	II	III	IV	Total inertia
Eigenvalues	0.680	0.361	0.200	0.170	3.061
Species-environment correlations	0.984	0.914	0.976	0.935	
Cumulative percentage variance of species data	22.2	34.0	40.5	46.1	
Sum of all unconstrained eigenvalues					3.061
Sum of all canonical eigenvalues					2.347

for the progressive increase of fine particles and organic matter content in the sediment. The silt/clay contents found in intertidal areas were higher than described by Nombela and Vilas (1986-1987). This situation is not surprising. On one hand, the presence of *Zostera* spp. stabilizes the sediment (Nombela *et al.* 1995); on the other hand, intense culture of mussels on rafts is located at the study sites (Fig. 1) and in the greater part of Galician estuaries. This culture is an important human disturbance since it produces large quantities of fecal pellets that substantially modify sediment composition, increasing the clay fraction (Nombela *et al.* 1987, León *et al.* 2004). The granulometric change has an important impact on the benthos community and also affects trophic structure (Abella *et al.* 1996, Conde and Domínguez 2004). Moreover, anoxic situations can be produced by pellet sedimentation with high organic matter content under the rafts (Tsuchiya 2002). Since the biodeposits produced by one raft could reach 190 kg dry weight d^{-1} (Cabanas *et al.* 1979) and in San Simón there are 76 rafts, the effect of this activity reduces the depth in the inlet between 0.5 and 2 cm y^{-1}. However, this culture could be considered also as an important depurator because mussels ingest high quantities of particulate organic matter (Fernández Rodríguez *et al.* 1997).

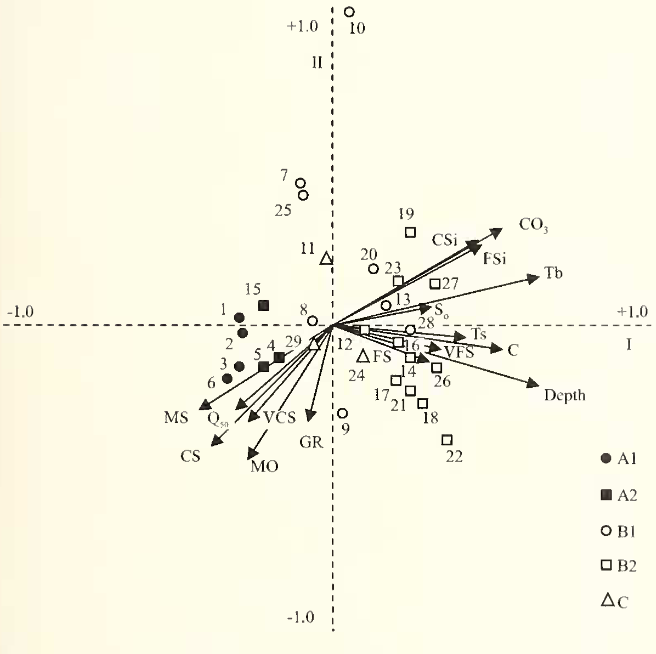

Figure 4. Canonical correspondence analysis ordination of environmental variables and sites in relation to axes I and II, representing the groups and subgroups in the classification analysis. Tb, temperature of bottom-water; Ts, temperature of surface-water; CO_3, carbonates; OM, organic matter; Q_{50}, median grain size; S_o, sort coefficient; GR, gravel; VCS, very coarse sand; CS, coarse sand; MS, medium sand; FS, fine sand; VFS, very fine sand; CSi, coarse silt, FSi, fine silt; C, clay.

Species richness, diversity, and evenness were greater on subtidal bottoms than on intertidal areas. This is a consequence of the stressful conditions that aquatic fauna must tolerate in intertidal areas: this fauna is subjected to important environmental changes such as extreme temperatures, desiccation, or rough conditions on the floor (Kikuchi 1987). The fauna in these intertidal sediments in the Ensenada de San Simón must also tolerate changes in salinity due to the freshwater input from several rivers (Vilas *et al.* 1995). Salinity fluctuations may greatly influence the species richness and the species composition of the community (Planas and Mora 1987), benefiting euryhaline species such as *Hydrobia ulvae*. As well as in Ensenada de San Simón, large densities of *H. ulvae* are common in inner areas of other Galician estuaries having organic pollution (Planas *et al.* 1984, Currás and Mora 1990, Junoy 1996, Olabarría *et al.* 1998). This species has a broad range of food sources since it is a detritivore on organic remains and fecal pellets (Jacobs *et al.* 1983) or grazes on microalgae (Muus 1967) which may explain the large numbers in these sediments.

Intertidal sediments colonized by *Zostera noltii* and *Zostera marina* showed low diversities of molluscs. Seagrass meadows provide a complex habitat that may be colonized by many species (Somersfield *et al.* 2002), stabilizing the sediment and providing protection to potential prey. However, low diversities characterize these meadows in San Simon since they are located in areas subjected to abrupt salinity changes, a major limiting factor for non-euryhaline species (Planas and Mora 1987, Junoy 1996). Subtidal sediments show more stable conditions in terms of salinity and currents (Nombela *et al.* 1987). However, the sites with the lowest species richness and abundance were the muddy bottoms close to the mouth of freshwater channels and in the harbor. Fine and homogeneous sediments have been related

Table 2. Summary of biotic and physical characteristics of the associations. Values: mean ± *SD*. Depth <2 m is intertidal; Q_{50}, median grain size; Bt, bottom type (VCS, Very coarse sand; CS, Coarse sand; MS, Muddy sand; M, Mud); OM, percent total organic matter content; CO_3, percent carbonate content. Faunistic parameters at each site per m^2: S, species richness; A, abundance; J, Pielou's evenness; H′, Shannon-Wiener's diversity index.

Group	A1	A2	B1	B2	C
Depth (m)	1.60 ± 0.00	1.73 ± 0.11	3.10 ± 0.88	9.04 ± 7.77	3.23 ± 1.10
Q_{50}	0.31 ± 0.56	0.77 ± 0.38	0.06 ± 0.08	0.15 ± 0.45	0.01 ± 0.00
% Gravel	5.85 ± 10.23	17.08 ± 10.82	3.23 ± 4.12	6.20 ± 11.66	0.03 ± 0.05
% Sand	45.83 ± 26.37	77.58 ± 12.52	36.46 ± 26.40	26.32 ± 10.00	17.72 ± 12.26
% Silt/Clay	48.31 ± 34.88	5.34 ± 2.50	60.30 ± 28.67	67.49 ± 20.35	82.25 ± 12.31
Bt	M-VCS	MS-CS	M-MS	M-MS	M
% OM	17.45 ± 11.42	2.69 ± 1.63	17.59 ± 11.61	17.17 ± 4.95	20.75 ± 6.11
% CO_3	7.30 ± 3.13	7.23 ± 0.96	4.74 ± 1.21	8.04 ± 10.89	4.44 ± 0.37
S	6.75 ± 1.5	15.67 ± 5.03	11.62 ± 3.25	17.73 ± 6.35	3.67 ± 2.89
A	159589.29 ± 139930.00	26916.79 ± 17955.36	8218.57 ± 7489.64	8207.14 ± 6280.71	1202.50 ± 898.21
J	0.06 ± 0.22	0.41 ± 0.17	0.69 ± 0.22	0.62 ± 0.14	0.61 ± 0.33
H′	0.16 ± 0.06	1.56 ± 0.63	2.43 ± 0.82	2.56 ± 0.82	0.93 ± 0.59

Table 3. Characteristic species of each group according to SIMPER and F × D values are listed indicating their constancy (Ct, constant; C, common; VC, Very common) and fidelity (Ex, Exclusive; El, Elective; Pr, Preferential; Ac, Accessory; Oc, Occasional).

A1	A2	B1	B2	C
Hydrobia ulvae (Ct, Oc)	*H. ulvae* (Ct, Oc)	*H. ulvae* (Ct, Oc)	*Calyptraea chinensis* (Ct, Ac)	*H. ulvae* (Ct, Oc)
Cerastoderma edule (Ct, Oc)	*Retusa truncatula* (Ct, Pr)	*Turboella radiata* (VC, Ac)	*Nucula nitidosa* (Ct, El)	*T. radiata* (VC, Ac)
Chrysallida terebellum (Ct, Oc)	*C. edule* (Ct, Oc)	*C. terebellum* (Ct, Oc)	*Thyasira flexuosa* (Ct, Ac)	*L. lacteus* (C, Oc)
	Tapes decussatus (Ct, El)	*Parvicardium exiguum* (VC, Ac)	*Mysella bidentata* (Ct, Ac)	
	Lepton nitidum (Ct, El)	*Rissoa labiosa* (C, Oc)	*Abra alba* (Ct, Ac)	
	Ostrea edulis (C, El)	*Loripes lacteus* (VC, Oc)	*Hyala vitrea* (C, Ex)	
	C. terebellum (VC, Oc)	*Abra nitida* (C, Pr)	*Myrtea spinifera* (C, Ex)	
			Chrysallida fenestrata (C, Ex)	
			Corbula gibba (C, Ex)	

to low diversities: as the grain size decreases, there are restrictions in interstitial space and oxygen diffusion (Olabarría *et al.* 1998). In general, diversity values observed in the Ensenada de San Simón were high (1.92 ± 1.13) in comparison to other Galician estuaries with a predominance of muddy bottoms (López-Jamar and Mejuto 1985). Mean diversity values were generally greater in exposed estuaries with sandy and more heterogeneous sediments, as Ría de Ares-Betanzos (2.38 ± 0.82, mean ± *SD*, Troncoso and Urgorri 1991), Ensenada de Baiona (2.37 ± 0.74, mean ± *SD*, Moreira *et al.* 2005), and Ría de Aldán (2.77 ± 0.84, mean ± *SD*, Lourido *et al.* 2006).

The assemblages in the Ensenada de San Simón determined by the different multivariate approaches could be described as classic communities or facies. The assemblage in the intertidal areas corresponding to Group A had the typical fauna of the small *Macoma* community (community of *Cerastoderma edule-Scrobicularia plana*). The facies located in areas associated with meadows of *Zostera* spp. (A1) was dominated by *Hydrobia ulvae*; the second facies (A2) presented a high dominance of *H. ulvae*, *C. edule*, and *Tapes decussatus*. Similar faunal assemblages have been reported from other intertidal and shallow bottoms in the Galician estuaries (Cadée 1968, Anadón 1980, Mora 1982, Troncoso and Urgorri 1991, Mazé *et al.* 1993). In estuarine bottoms with high organic content cited by Junoy (1996) and Olabarría *et al.* (1998), the assemblage tends to be dominated by *H. ulvae*. An impoverished facies of a small *Macoma* community was present in reduced muddy bottoms (Group C). In this case, salinity fluctuations coupled with effects from

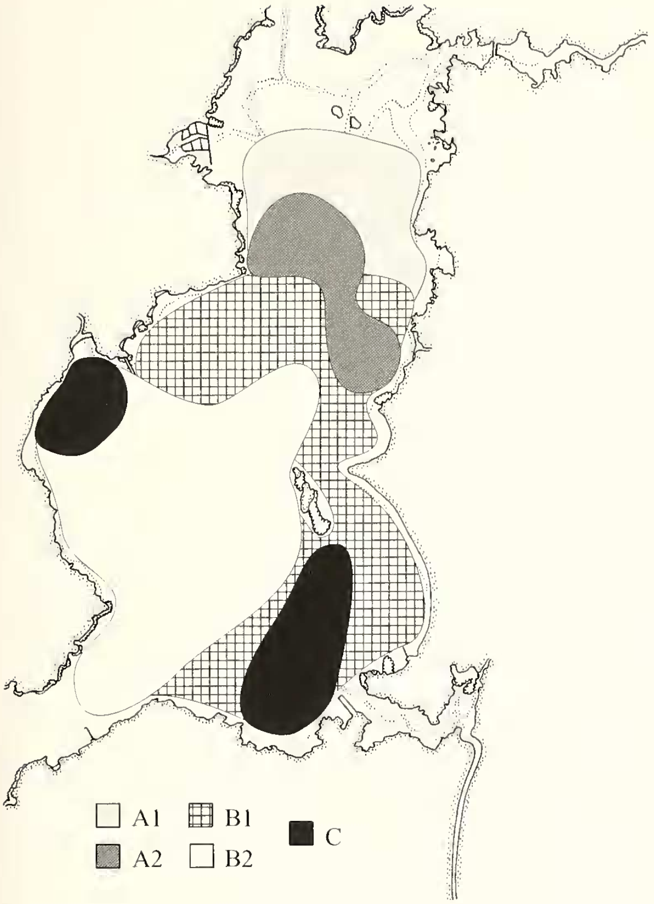

Figure 5. Spatial distribution of molluscan assemblages in the Ensenada de San Simón, Spain.

human activities, such as organic enrichment and sewage disposal, may be responsible for the scarce malacological fauna near shore.

Group B can be ascribed to the *Abra alba* community (Petersen 1918) from muddy bottoms (Lastra *et al.* 1990). The facies present in subgroup B1 had a transitional fauna that was between that of the small *Macoma* community (*e.g.*, *Hydrobia ulvae*, *Rissoa labiosa*), and of a typical *A. alba* community, with species that tend to be more abundant in muddier sediments, such as the bivalves *Abra nitida*, *Mysella bidentata*, and *Thyasira flexuosa*. The facies in deeper bottoms of Subgroup B2 was characterized by the greater dominance of *T. flexuosa* and *M. bidentata*. Similar assemblages, showing transitional faunas between typical "communities" (as in Thorson 1957) both in composition of species and numbers for any given species according to gradients in depth and granulometry, have been reported by Sánchez-Mata and Mora (1999), Moreira *et al.* (2005), and Lourido *et al.* (2006) in a variety of muddy bottoms of Galicia. *T. flexuosa* has been considered as an opportunist in disturbed situations (López-Jamar and Mejuto 1988) and prefers muddier sediments (Moreira *et al.* 2005), as was the case in San Simón. López-Jamar and Parra (1997) detected high faunal abundances in similar bottoms of the Galician coasts.

In conclusion, the most important factors in determining distribution patterns of molluscs in the Ensenada de San Simón were depth, grain size, and total organic matter content. The presence of muddy sediments in this inlet is a consequence both of the hydrodynamic regime, which deposits finer fractions in subtidal areas, and mussel bivalve culture. Similarities both in sediment and faunistic composition have been reported by Mora *et al.* (1989) in Ensenada de Lourizán, López-Jamar and Mejuto (1988) in A Coruña harbor, Lourido *et al.* (2006) and Sánchez-Mata and Mora (1999) in inner areas of Ría de Aldán and Ares-Betanzos, or Olabarria *et al.* (1998), Mora (1982), and Junoy (1996) in the *Zostera* meadows in Ensenada de O Baño, O Grove, or Ría de Foz, respectively.

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Appendix 1. Depth (<2 m is intertidal) and characteristics of sediments at each site. Q_{50}, median grain size; CO_3, percent carbonate content; OM, percent total organic matter content (% based on dry mass).

Site	Depth (m)	Q_{50}	Gravel (%)	Sand (%)	Silt/Clay (%)	Bottom type	OM (%)	CO_3 (%)
1	1.6	0.01	0.1	16.8	83.1	Mud	26.52	5.52
2	1.6	0.01	2.2	32.9	64.9	Mud	23.30	5.60
3	1.6	0.08	0.0	56.7	43.3	Sandy mud	19.05	6.12
4	1.6	0.32	17.8	74.0	8.2	Muddy sand	2.16	6.00
5	1.8	1.25	30.0	64.3	5.7	Muddy sand	4.90	7.33
6	1.6	1.15	21.1	76.8	2.1	Very coarse sand	0.95	11.98
7	3.4	0.15	0.3	74.3	25.4	Sandy mud	3.95	6.31
8	3.2	0.04	0.6	35.9	63.5	Mud	10.88	5.80
9	2.9	0.01	0.9	27.7	71.4	Mud	18.12	4.28
10	2.9	0.01	0.0	2.3	97.7	Mud	36.93	4.28
11	3.6	0.01	0.0	8.9	91.1	Mud	26.50	4.81
12	3.8	0.01	1.1	19.2	79.7	Mud	19.93	2.12
13	3.5	0.01	3.0	23.0	74.0	Mud	23.00	2.36
14	4.6	0.01	7.1	24.4	68.5	Mud	19.78	2.28
15	1.8	0.74	3.5	94.4	2.1	Coarse sand	1.00	8.35
16	4.2	0.01	1.0	15.5	83.5	Mud	21.47	4.53
17	3.7	0.02	4.7	31.1	64.2	Mud	18.93	5.90
18	4.5	0.01	1.9	20.0	78.1	Mud	15.20	4.52
19	4.7	0.01	0.0	13.9	86.1	Mud	21.05	4.53
20	2.6	0.21	11.8	77.7	10.5	Muddy sand	1.80	4.85
21	18	0.01	0.6	26.3	73.1	Mud	19.50	4.61
22	10.4	0.01	1.0	37.4	61.6	Mud	12.98	5.51
23	5.9	0.01	1.2	25.2	73.6	Mud	22.17	5.40
24	4.1	0.01	0.0	12.6	87.4	Mud	21.42	4.07
25	1.6	0.01	6.8	31.8	61.4	Mud	23.72	5.47
26	28.2	1.50	40.2	48.3	11.5	Muddy sand	7.22	40.46
27	11.5	0.01	9.3	28.2	62.5	Mud	10.60	8.61
28	4.7	0.01	2.4	19.0	78.6	Mud	22.32	4.61
29	2	0.01	0.1	31.7	68.2	Mud	14.33	4.45

Appendix 2. Faunistic parameters at each site: S, species richness; A, total abundance (individuals/m^2); J, Pielou's evenness; and H′, Shannon-Wiener's diversity index.

Site	S	A	J	H′
1	6	2,982.1	0.09	0.24
2	8	15,014.3	0.05	0.14
3	5	10,246.4	0.04	0.09
4	15	821.4	0.61	2.37
5	11	2,139.3	0.42	1.47
6	8	35,592.9	0.05	0.16
7	13	1,385.7	0.48	1.77
8	17	1,189.3	0.62	2.54
9	13	207.1	0.88	3.26
10	6	2,178.6	0.29	0.75
11	7	157.1	0.54	1.51
12	9	157.1	0.60	1.91
13	11	107.1	0.90	3.10
14	21	2,467.9	0.63	2.78
15	21	5,114.3	0.19	0.83
16	13	653.6	0.34	1.25
17	16	925.0	0.47	1.90
18	13	303.6	0.57	2.10
19	12	717.9	0.49	1.75
20	11	396.4	0.83	2.88
21	16	332.1	0.73	2.91
22	31	1,117.9	0.74	3.65
23	18	796.4	0.68	2.84
24	2	17.9	0.97	0.97
25	13	1,014.3	0.64	2.37
26	22	1,046.4	0.74	3.28
27	24	510.7	0.82	3.75
28	9	96.4	0.88	2.79
29	2	185.7	0.32	0.32